ASSESSMENT OF RELIABILITY AND OPERATIONAL ISSUES FOR INTEGRATION OF RENEWABLE GENERATION

BACKGROUND MATERIAL FOR CALIFORNIA ENERGY COMMISSION STAKEHOLDER WORKSHOP

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California Energy Commission

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Project Background and Purpose

California has led the nation in the development of its renewable resources. The California Energy Commission's Renewable Energy Program began in 1998 to help increase total renewable electricity production statewide. This followed decades of bi-partisan legislative and gubernatorial support for renewable energy helping to make California a recognized leader in the field.

The current program provides market-based incentives for new and existing utility-scale facilities powered by renewable energy. It offers consumer rebates for those installing new renewable energy systems. The program also helps educate the public regarding renewable energy.

The California Renewables Portfolio Standard (RPS) was passed by the California legislature in September 2002 mandating energy production from renewables resources to account for 20 percent of the annual energy production by 2017. In May 2003, the California Energy Commission (Energy Commission), California Public Utilities Commission (CPUC), and California Power Authority called for the acceleration of renewable integration setting the goal of 20 percent by 2010. And in November 2004 the Energy Commission’s *Integrated Energy Policy Report 2004 Update* called for a proactive approach to transmission planning for renewables development: phased development plans for transmission upgrades in remote areas must be developed and will be essential to meeting statewide RPS goals in a timely and cost effective manner.

Renewable resources offer the benefits of price stability, resource diversity, reduced dependence on fossil fuels, and reduction in environmental impacts. These benefits are important for California consumers. Substantial increase in renewables is likely to raise operational and resource integration issues that may hinder and delay renewables development. Consequently, it is important to proactively address issues that are likely to arise for integration of renewables in the energy mix. Integration issues are impacted by the location of the resource, as renewables are frequently located remote from customer loads and require the development of new transmission and interconnections to deliver the output of renewable resources to consumers, and the intermittent nature of certain renewable resources, which collectively present operational and reliability integration issues to system operators. The operating and reliability issues are impacted by the type and level of renewables in the capacity and energy mix.

There are many strategic policy issues related to reliability and operations for integration of renewables in California. Historically, these issues have been addressed individually and often litigiously. As the level of renewables in the energy mix increases, the number of reliability and operational issues are expected to increase. To meet the objectives of the RPS and accelerate development of renewables, California needs a predictable policy framework for operational integration of new renewables.

To address these issues, a study is underway that will review, assess, catalog, and report on experiences and best practices from other regions for integrating large amounts of renewables. The study will culminate in a final report that will make recommendations in June 2005, in time to be integrated into the *Integrated Energy Policy Report* (IEPR) process. The steps involved in this study process are:

1. Review and assess papers and studies related to the integration of renewable resources.

2. Catalog experiences associated with renewables integration in California and other selected regions and determine the best practices and lessons learned which will foster renewables integration in California.

3. Conduct an initial stakeholder workshop to seek input and validate the issues from steps 1 and 2. (February 2005)

4. Catalog operational integration and reliability issues through dialogue with key utilities, stakeholders, and independent system operators.

5. Analyze operational integration issues by resource type, location, and identify alternatives and options for integrating renewables.

6. Evaluate alternatives to address reliability and operational integration issues, including resource management, operating procedures, and regulatory policies. Assess pros and cons for alternative policy options.

7. Review options in the areas of policy, procedure, and standards at a second stakeholder workshop. (April 2005)

8. Prepare a final report and recommendations. (June 2005)

Purpose and Expected Outcome of the February 3 Stakeholder Workshop

The purpose of the scheduled workshop is to review the project findings from items 1 and 2 (above) in an open forum with all stakeholders.

The expected outcomes from the workshop are:

- Validate list of issues identified for the project.
- Identify if there are any gaps in the list of issues.
- Obtain stakeholder feedback on description of issues and any suggested modifications.

- Determine if the project is headed in the right direction and is adequately focused.

Project Work Plan and Current Status

The EPG/CERTS work plan for this project is as follows:

1. Review and assessment of papers and studies related with integration of renewable resources.
   List of documents reviewed
   Identification of gaps and issues
   Status – Completed

2. Stakeholder Validation – seek agreement on:
   Reliability and operational integration issues
   Resource development
   Resource location
   Status – In progress – completion date January 28, 2005

3. Energy Commission Staff briefing:
   Review study findings to date
   Review work plan
   Seek approval of work plan.
   Status – Briefing held on December 15, 2004

4. Energy Commission Workshop:
   Review findings from above items 1 and 2 with all stakeholders in an open forum.
   Status – Planned for February 3, 2005

5. Analysis of operating integration issues by:
   Resource type.
   Location.
   Assessment of alternatives
   Status – Planned completion February 28, 2005

6. Review of options in the following areas for the integration of renewable resources:
   Policy
   Procedures
   Standards
   Status – Planned completion March 31, 2005

7. Energy Commission Workshop for stakeholder final review
   Status – Planned completion April 30, 2005

8. Final report recommendations and integration with the Energy Commission's IEPR
   Status – Draft version to Energy Commission staff by June 1 and final version by June 15, 2005

Workshop Agenda

Open the Workshop and discuss the background and scope of the project by a member of the Energy Commission or staff.

Review the project work plan, studies and reports by a CERTS representative.

- How the stakeholders were identified
- How the list of issues was developed

Review each item on the Issue List, using the following format:

- Describe each issue clearly
- Provide an example, where possible
- Identify the impact on reliability and operations integration
- Identify stakeholder feedback
- Identify the differences of opinion that have surfaced during the interviews, the areas of potential conflict, and the areas on which to concentrate.
- Provide a summary of best practices and lessons learned which will foster renewables integration in California.
- Propose mapping issues for resolution.

California Independent System Operator (CA ISO) Presentation of White Paper *Interconnection of Intermittent Resources* by Yuri Makarov

Resource Technology Presentations (responding to relevant issues)

Wind – General Electric, by Nick Miller or his representative
Solar – TBD
Geothermal – TBD

Stakeholder panel discussion by a renewable power producer, a policy maker and two utility representatives.

Is the list of issues valid?
Are any issues or potential issues not on the list?
Is the project is headed in the right direction and adequately focused?

Open Comment Period

Next Steps

Stakeholders can provide written comments to the Energy Commission by February 15.

Continuing project work:

- Analyze operational integration issues
- Evaluate alternatives to address reliability and operational integration
- Review options (e.g., policies, procedures, standards) to enhance integration
- Workshop for stakeholder second review – late April
- Final report recommendations in June 2005 in time to integrate with the Energy Commission's IEPR schedule.

List of the Stakeholders Interviewed

The following is a list of the stakeholders that were interviewed as part of this Energy Commission project:

California Independent System Operator
Web site – www.caiso.com

California Wind Energy Collaborative
Web site - http://cwec.ucdavis.edu/

Center for Energy Efficiency and Renewable Technology (CEERT)
Web site - http://www.ceert.org/

Imperial Irrigation District (IID):
Web site – www.iid.com

Los Angeles Department of Water and Power (LADWP)
Web site – www.ladwp.com

PPM Energy
Web site - http://www.ppmenergy.com

Pacific Gas and Electric (PG&E)
Web site – www.pge.com

Royal Institute of Technology, Sweden (Thomas Ackermann, Ph.D.)
Web site - http://www.kth.se/eng/index.html

Sacramento Municipal District (SMUD)
Web site – www.smud.com

San Diego Gas and Electric (SDG&E)
Web site – www.sdge.com

SolarGenix Energy

Web site - www.solargenix.com

Southern California Edison (SCE)
Web site - www.sce.com

Vulcan Power
Web site - www.vulcanpower.com

Master Stakeholder Issues List

The Project Team identified a list of issues for integration of renewables based on literature reviews. Many of these issues have been documented in reports from E.On Netz in Germany and Eltra in Denmark. Both E.On Netz and Eltra have significant penetration of renewables and their experience provides good insight on the issues likely to be faced by California. Additional data sources were Energy Commission, CA ISO and other reports.

The issues were discussed with stakeholders in interviews. The stakeholder feedback, in general, was that the list complete and captured all or most of the issues facing California. There are some stakeholders that feel an issue or two from the list have been already addressed (i.e. low voltage ride through), but they acknowledge it has been done in forums outside of California. Feedback from the stakeholders has been incorporated to revise the issues list and description. The master list of issues based on literature review, project team expertise and stakeholder feedback is summarized below.

Load Following (includes both following load and intermittent generation)

The control area operator is responsible for ensuring that the control area is operated within the WECC and NERC standards. This includes meeting minute to minute changes in both load and generation by controlling some generation on the grid to constantly balance load and generation.

1. In the case of the CA ISO, who is responsible for ensuring the control area operator (CAO) has adequate generation capable of providing load following and ramping services?

2. Will the resource additions to meet the state’s accelerated RPS requirement exceed the expected load growth?

3. Will plant retirements affect the ability to meet the load following and ramping requirements.

4. What options are available to limit the high rate of change of energy production from intermittent energy (e.g., wind, solar, hydro, and geothermal) production?

5. Is there any diversity among the control area's existing wind resources that would mitigate some of the challenges of wind energy integration?

6. From the control area perspective, is the production from the following intermittent energy sources correlated with customer demands?
   Wind
   Solar
   Small hydro

7. If the control area was to meet the 2010 accelerated RPS what would the load following and ramping requirements be?

NERC CPS Standards

The NERC has established Control Performance Standards for control area operation to ensure that each control area diligently and effectively balances its generation with load on a continuous and consistent basis. Poor CPS performance indicates that the control area is unacceptably relying on neighboring systems to help balance load and generation, and is a leading indicator of potential operating reliability risks.

1. In the last three years (2002-04) has the control area been in compliance with the NERC/WECC CPS?

2. Has any assessment been made of the control area's ability to comply with the NERC CPS standards, considering potential retirements and accelerated renewable generation additions via the RPS?

3. How much generation under dynamic (Automatic Generation Control (AGC) or equivalent) control is needed to meet the CAO CPS requirement? What quantity of intermittent generation is assumed to be included in the mix for this level of control requirement?

Storage

Storage has been identified as one means of improving the resource value of intermittent energy sources by shifting energy produced during off peak periods into peak load periods and mitigating minimum load impacts.

1. Are there any plans to utilize some form of energy storage system to improve the effectiveness of intermittent energy? If so, describe and quantify.

2. Is location of energy storage a critical integration issue? (E.g., energy storage close to an intermittent generating facility could increase the overall effectiveness and utilization of the transmission grid.)

3. Should energy storage be required for intermittent energy additions which cause the energy mix on the grid to exceed a specific level?

4. Who should decide and who should be responsible for providing?

Minimum Load

High levels of off-peak energy production (e.g., from, baseload, existing contracts, hydro runoff/run of river and intermittent energy resources) pose operating problems for the control area operator, the transmission operator, and the energy supplier (retail supplier).

1. Does the control area presently experience minimum load conditions?

2. What options are presently used to manage/mitigate minimum load conditions?

3. With an increasing mix of renewable energy resources, will these options continue to be effective?

4. What options are available to limit the high rate of change of energy production and production when it exceeds the forecast for the hour or 15 minute interval from intermittent energy production?

5. How many MWs (or percent of resource mix) of renewable resources could be added to the control area's resource (portfolio) mix before the minimum load impact becomes unmanageable?

Reserves

The accurate determination of generating resources and reserves is essential to maintain operating margins for safe and reliable operation.

1. How does the utility determine the dependable operating capacity (DOC) of intermittent resources?

   If the DOC is derated from nameplate, what factors influence the derate?

   Is there a consistent method by all stakeholders in the state (i.e. utility, control area, regulator)?

2. Currently, both the Energy Commission and the CA ISO assign derates to intermittent generation in computing planned reserve levels. How do you (utility within CA ISO control area or other COAs) account for intermittent generation in your reserve margin planning?

3. Should the forecast level of operating reserve margins be contingent on the forecast of intermittent generating resources in the daily/hourly plan?

   If yes, by how much?

   Who should set the standard?

4. At what level of intermittent generation increases, within the control area, will the current methodology for determining operating reserve margins change? Please explain.

5. Should operating reserves be distributed locationally in proportion to the intermittent generation?

6. Will there be a need for shadow generation as we introduce greater amounts of intermittent resources in the state's resource mix?

7. How much will be required?

   What should the strategy be to meet this need?

Forecasting Intermittent Resources

Accurately forecasting both the hourly load and the hourly generation are important in maintaining adequate resources and reserve margins for reliable operation.

1. What is the utility/control area's typical <u>load</u> forecast error during summer and non-summer periods?

   What is the utility/control area's typical daily <u>resource</u> forecast error (MW and percent) related to intermittent generating resources during summer and non-summer periods?

   Is this expected to change significantly in the future, taking into account geographical diversity of intermittent resources within the utility's grid

2. What would the reliability impact be if, as a result of the RPS, the utility/control area experienced a 10 percent, 30 percent, 50 percent (or more) intermittent generation forecast error, taking into account the morning and evening load ramp?

3. Would the impact be different during the summer vs. the non-summer periods?

4. Describe the strategy the utility/control area will use to mitigate intermittent generation forecast errors.

5. Is there historical data on the production from existing intermittent generation projects (e.g., wind and solar)?

   If so, has it been analyzed?

   If so, what can we learn (e.g., performance at peak, rate of changes in production, periods of max production)?

6. Should standards be established related to the acceptable daily forecast error for intermittent renewable resources?

California Resource Mix

1. What is the desirable mix of resources (base, intermediate, peaking) for the utility's area to assure RPS resource integration?

2. What agency/organization should be responsible for determining the appropriate quantity of resources providing ancillary services?

3. Should achieving an "appropriate" resource mix be a part of the RPS achievement goals?

4. Should some agency/organization be responsible for planning for an appropriate amount of ramping, load following and regulation for the control area, and if so, who?

5. Should standards be established related to the CAO's resource mix or resource attributes?

Voltage

1. What voltage performance (grid support) can be expected or requested from renewable generation?

   Wind
   Geothermal
   Solar
   Small hydro

2. There is already a voltage performance standard for thermal generation in the WECC voltage regulator standards, which require the addition of a suitable voltage regulator and power system stabilizer.

3. Should a voltage response performance standard for renewable generation be considered or required?

   If so, what level of performance should be required, and what group should develop the standard?

   Who should be responsible for monitoring and enforcing compliance to the standard?

4. Is the present level of voltage control adequate in the following specific areas:

   Tehachapi
   Imperial Valley

   If not, please elaborate on the changes needed

5. What will the voltage and VAR support requirements be for every 500 MW increase of renewable generation in the Tehachapi area?

6. What will the voltage and VAR support requirements be for every 500 MW increase of renewable generation in the Imperial Valley area?

7. What will the grid voltage and VAR support requirements be to move the renewable energy, under various development scenarios, from the Tehachapi area to some of the likely receiving utilities?

8. What will the grid voltage and VAR support requirements be to move the renewable energy, under various development scenarios, from the Imperial Valley to some of the likely receiving utilities?

Frequency Deviations

The WECC Minimum Operating Reliability Criteria describe minimum expected performance of a control area's combined generation with respect to load/generation imbalance and frequency response. Furthermore, the WECC Coordinated Under frequency Load Shedding programs depend on certain anticipated generator performance during high or low frequency excursions.

1. What electrical governor performance (grid support) can be expected or requested from renewable generation?

Wind
Geothermal
Solar
Small hydro

2. There is already an electrical governor standard for thermal and hydro generation in the WECC standards.

3. Should an electrical governor performance standard for renewable generation be considered or required?

4. If so, what level of performance should be required, and what group should develop the standard?

5. Who should be responsible for monitoring and enforcing compliance to the standard?

6. For boiler-type thermal generators, the energy output remains essentially constant for small changes in frequency around 60 Hz, absent any action from the electrical governor. Similarly, for single shaft combustion turbine generator sets, the energy output varies at the square (or cube) of the change in electrical frequency.

7. What is the relationship between the energy output and the electrical frequency for intermittent generation during disturbances?

8. What electrical governor-like energy output performance can be expected from renewable generators, especially intermittent generators?

9. From the control area and WECC perspective, is the present level of electrical governor response adequate to manage the grid?

10. If the utility's level of renewable generation were increased to 5 percent, 10 percent, 20 percent of total mix, would the level of electrical governor response be adequate to manage the grid?

11. What are the under/over frequency trip points for the existing renewable generation resources?

    Wind
    Geothermal
    Solar
    Small hydro

12. If future renewable resources tripped off line at the same trip points as existing facilities (based on utility-specified protection), what would the reliability impact be for every 10 percent of additional renewable resources connected?

Retirement Risk of California - Controllable and Replacement (Shadow) Generation

Many of the controllable generators in the present resource mix are possible candidates for retirement. Many of the renewable generators are not as readily controllable, such as for load following and ramping services.

1. Who should have the responsibility to ensure the control area has an adequate amount of controllable generation?

2. What is the appropriate level of controllable generation, and how should that level be determined?

Congestion

Much of California's renewable resources potential is located regionally (for instance, much of the identified wind potential is located in SP15). As the utilities seek to meet the RPS, it is possible that renewable energy may need to be transferred from one part of the state to other parts across key transmission facilities.

1. Will the impact of this be evaluated, and if so, in what process?

2. Where will renewable energy fit in the curtailment priority ranking when congestion exists?

3. What steps are needed to assure the California customers get the full benefit (e.g., deliverability and integration) of the renewable resources that are connected to the grid?

California Import Capability and WECC Impacts

1. At what level does California currently rely on its import capability to meet energy, daily load following, ramping, regulation, or ancillary services requirements?

2. Is there a potential for a significant resource mix change in California to have regional implications?

3. Many utilities throughout the WECC are in the process of including greater amounts of renewables in their resources mix. Has the WECC assessed the impacts of the changing portfolio mixes in the region?

4. What do California and others in the WECC need to do to maintain existing transmission path ratings that could be impacted as a result of significant changes in the regions generation resource mix (e.g., addition of baseload, resources with limited or no electrical governor response)?

Operational Issues

What are the key operational issues you experience which appear to be caused by renewable resources connected to your grid?

Feedback from the Stakeholder Meetings/Interviews

Prior to publishing this document, the Project Team interviewed eight organizations to solicit their feedback on the “major issue list” and to get their overall comments on the various challenges California faces in achieving its RPS goal. Below are lists of the stakeholders interviewed and their comments:

CA ISO	CEERT
IID	PG&E
PPM	SCE
SDG&E	SolarGenix

Load Following (includes both following load and intermittent generation)

There is concern that the majority of the regulating capability was in NP15, so that connecting all the wind to SP15 would pose operational challenges.

There should be a policy approach to bringing the public power and the CA ISO together to facilitate operations. If we could look at all the resources (both CA ISO and municipal), it would provide more resources with which to regulate the grid. If the RPS is a state policy, then there may be a basis for more integrated control of state resources to accommodate more wind.

The geothermal units seem to chose, for economic reasons, to run their units with the electrical governor essentially bypassed, at full throttle.

More of the geothermal units need to be on AGC.

What operating reserve level is needed to accommodate intermittent resources? The present reserve levels of 7 percent for thermal, and 5 percent for hydro may not be adequate for wind.

The issue of serving the state's coincident needs vs. the individual utility peaks is being discussed – everyone realizes that planning to serve the state's needs is more efficient, but there are problems with the methods of compensation

New generation has less control than old generation – the control area operator will need faster response than the new technologies are providing—some of the generation will need to be AGC capable.

Storage

Don't look at storage as a means of "firming up" renewables into standard products, as that simply creates the ramping problem again. The grid doesn't need more standard product production.

Minimum load is an existing issue now – it is not being created by renewables.

Solar will not be built without storage – it is very cost effective to include gas burners to provide heat when clouds come over.

There is a procurement system to allow intermittent generators to handle production risks economically—called Participating Intermittent Resource Program. This provides hourly energy production goal, generator than tries to average its production to that level. Month end settlements of imbalances are thus smaller. Still need some rules to handle the big swings. Is this type of procurement system sustainable with much higher penetration of intermittent resources?

Minimum Load

Wind generation is highest in January and February – see big volatility in power output when wind speed exceeds maximum turbine speed, turbine cuts out, then restarts when wind slows below maximum. Need new procedures/technology to solve this problem.

Minimum load is aggravated in April-May with hydro runoff, especially nighttime.

Reserves

Make a distinction between dependability and predictability. Wind generation may be dependable (as in, the machine reliability is high), but unpredictable (as in, the wind forecast is inadequate).

Standards should be set by NERC/WECC for reserve requirements for systems with intermittent generating resources.

If we spread the resources over a broader area, we will likely experience fewer simultaneous problems.

The new wind turbine technology boosts energy output from about a 25 percent capacity factor to around 40 percent.

Whether operational reserves should be distributed locationally in proportion to intermittent resources is a big issue. If congestion shows up on a transmission line, can renewable resources partially curtail their output to relieve congestion, or does the entire facility need to be curtailed? We need to be sure we have the flexibility in operations to partially curtail output to relieve operating problems.

With much higher levels of intermittent renewable generation, generation reserve planning/forecasting may need more sophisticated tools than the present 5 percent - 7 percent rules in place in WECC.

Forecasting Intermittent Resources

There is a lack of good wind production data to allow analysis. The wind generators are reluctant to provide data, as they consider it commercially proprietary information.

It is recommended to develop a protocol to enable wind producers to supply wind data on a confidential basis.

The geothermal generators provide a day ahead schedule, and they are pretty good at meeting that schedule (except for the minor fluctuations during the hour).

Better wind monitoring is needed, especially upwind of wind parks, to facilitate better energy forecasting from wind farms. National Weather Service wind monitoring is not adequate to support CA ISO wind energy forecasting needs (ok for airports but not energy).

Possibility of collaborating with colleges/universities to get more widespread metering of weather. Perhaps the Energy Commission would be willing to pay for metering sites.

California Resource Mix

The grid needs a reasonable mix of resources, with probably not more than 40 percent which is base loaded, and not less than 20 percent with peaking capability to cover the cycling needs.

Geothermal behaves like a base loaded plant, and doesn't ramp well. Ramping creates some problems with the wells and collector systems – such as brine buildup.

We need better descriptors for the components of the resource mix. Base, intermediate and peaking are not sufficiently descriptive any more. We need to also address the control attributes, such as load following, regulation, etc.

Resource planning will likely be a joint process (involving at least the other utilities and the CA ISO), but the utilities will then be obliged to procure the required resources/mix/control capability.

Solar generation performance is not equivalent to wind – it's not right to compare the economics of those two technologies together since they deliver different products.

It would make sense to set prices for each type of energy needed by the grid – base, intermediate, peaking, and then compare the renewable technologies to those goals. Concern about loss of peaking capacity.

Voltage

A grid code has been proposed to FERC for wind generation. Most of the geothermal generators are synchronous generators, except for a few smaller units, which are induction generators. All have static exciters and Power System Stabilizers.

What is the state of the art of technology for the renewable machines? What can the new machines produce in the way of voltage control – it may be different from the performance of the older machines?

It may not matter who provides the voltage control service, but it is important to ensure that the service is provided, and in an appropriate location (e.g., dynamic voltage control).

For every 100 MW of generation added to the grid, the grid also needs at least 50 MVAR of reactive capability.

Where the power is actually scheduled matters – if power is scheduled to move from one area to another, there may be a need for voltage support in an area away from the renewable generator producing the energy.

We need to be sure we have a process in place to ensure that the necessary detailed transmission studies are completed before it is time to evaluate the bids for renewable generation.

Who should be responsible for monitoring and ensuring compliance to the voltage standards?

Concern expressed about the Balkanization of the control areas which is ongoing (SMUD, including Western, TID, etc). This complicates grid voltage control.

Frequency Deviations

Most of IID's geothermal units stayed on-line during the July and August, 1996 WECC disturbances.

We need to have a dialog between the machine manufacturers (the suppliers) and the grid operators (the consumers) to level-set the expectations for machine performance for reliable grid operation.

New rules may be needed to address how much generation will remain within a locale during a low frequency event, to ensure that enough generation remains to balance the load which will remain.

Retirement Risk of California - Controllable and Replacement (Shadow) Generation

We need an industry standard process on how we describe and account for the attributes of generation that we need for reliable grid operations.

The procurement rules appear to suggest that the loading order will be renewables first. This will conflict with FERC rules for transmission access.

Congestion

Congestion is a problem at the state level.

Because of the FERC ruling which allows generators to connect to the grid without providing for any upgrades to the system, utilities are starting to see increases in unscheduled flow through their system. (This is caused by generators connecting to the grid near the boundaries of a utility's system.) New interconnection rules may be needed to keep new generators from adversely affecting adjacent system grids.

Where the transfer capability of a path is ensured by the use of a generator tripping RAS, we will need to address the location of reserves and the possible need to include those reserves in the RAS tripping scheme, to prevent the overload which the RAS was intended to eliminate from reoccurring due to the action of the reserve generation.

The Path 15 Upgrade depends on a RAS scheme to trip generation at Midway. To the extent that generation at Midway is reduced to allow more renewable energy imports from SP15, it may become necessary to include arming of the tripping of the renewable energy sources for loss of Path 15 in order to maintain the Upgrade rating.

FERC says that there is no “must take” concept when looking at transmission access – all generation should have equal access to the grid. This may interfere with the renewables procurement process and/or dispatch.

The CPUC process does not yet fully address the deliverability issue.

Under the present use of the term, deliverability is assessed as a static, on-peak test of whether transmission capacity is available for the scheduled energy deliveries on-peak. The test is not done for other than the single hour on-peak period. Thus, for generation which may have its highest output in other than peak hours, the present test of deliverability may not address the ability to move the full output of the project to the purchasing system.

California Import Capability and WECC Impacts

If the Western Governors endorse the accelerated renewables goal of 20 percent by 2010, then WECC will definitely need to assess the combined impacts of the change in generator performance.

The GE study tools (used by most of the members of the WECC) only have a limited number of wind models, while the PTI study tools appear to have a expanded selection of wind models. Many of the wind producers are unwilling to provide data to GE for modeling, as GE is also a competing wind turbine manufacturer.

Transmission planning is currently being hampered by a lack of clear, timely forecast information. As noted above, utility plans are late getting into the data base, and thus into the studies.

Other Operational Issues

We need to have transmission planning done in concert with resource planning.

The use of transmission import capability for wind creates costs – the import transmission capacity must be reserved for an entire hour even if the production will reach that capacity level for only a few minutes (see the CA ISO wind production chart to illustrate the hourly capacity change for wind).

FERC's direction regarding the design of the day ahead market contradicts the ability of the utility to participate in that market with renewable energy sources without economic harm. For example, for wind generation, the FERC market approach appears to be to treat all generation as equivalent. Thus, the imbalances which will naturally occur between the hourly wind schedule and actual production would be settled at an imbalance charge. The utility scheduling that generation would be responsible for that imbalance charge.

The CA ISO market cannot recognize the distinctions between standard products, such as a block of energy, and non-standard generation, such as wind. The differences between the standard products and the non-standard generation creates financial risk to the utilities.

In FERC's generator interconnection process, there are two steps, a preliminary interconnection study, and a detailed study. Where multiple projects are being studied in the queue, the study process fails to identify the best alternatives. For example, the first project requires only a reconductor, and per the procedure, would be assessed the reconductor cost. The second project, assuming the first project is completed, would require construction of a new line, and the reconductor project might not be needed.

There is no way in the process to show the different alternatives to the different suppliers/generators.

Regulatory Environment – Consider the timing of regulatory process.

Can we ask for an expedited transmission licensing process where renewable generators are being interconnected? The Energy Commission sets the renewables goals, but the CPUC licenses the transmission lines.

How much transmission should you build to make power deliverable, versus adding a RAS (remedial action scheme or special protection scheme). Should there be a standard to achieve some kind of uniformity in application?

The Western Renewable Energy Geographic Information System (WREGIS) is developing a system of Renewable Energy Credits bartering, and an open market, without limits on imports, will facilitate this market.

Organization of the Studies and Reports Reviewed

The following pages contain a list of the various studies, papers and reports the Project Team reviewed as part of this project, along with a brief summary of each of the documents.

The information is grouped according to author. The following groupings are used:

California Energy Commission
California Public Utilities Commission
California Independent System Operator
Transmission System Operators – International
Other Governmental
Other U.S. References
Other International References

Studies and Reports Reviewed

California Energy Commission

Resource, Reliability and Environmental Concerns of Aging Power Plant Operations and Retirements.

This report begins by describing the role that the aging power plants under study play in the overall electrical system from a physical perspective, as well as from the standpoint of regulation and operation. It then describes the analysis conducted by staff concerning both the effects on electric reliability from plant retirements, and the potential effect on reliability from forced outages at aging plants that continue to operate. The white paper then examines the economics of aging plant operations, and the resultant pressures on decisions to retire, as well as the likely alternatives to aging unit generation assuming retirements occur.

The report concludes with an examination of the implications to air emissions and other environmental impacts from both the continued operation of the aging boiler units, and from their retirement. The environmental analysis also examines factors that could increase the cost of continuing to operate the aging units, and therefore possibly contribute to decisions to retire. The scope of this study is limited to the present through the end of 2008, as this is the period during which the bulk of possible retirements are expected to occur. After 2008, decisions made during the resource adequacy and procurement proceedings at the CPUC are expected to be fully implemented, including development of needed new resources.

Draft Staff White Paper. Publication Number 100-04-005D. August 2004. [http://www.energy.ca.gov/ 2004_policy_update/documents/2004-08-26_workshop/2004-08-04_100-04-005D.PDF].

California Renewables Portfolio Standard Renewable Generation Integration Cost Analysis Phase III: Recommendations For Implementation.

The ultimate purpose of the Energy Commission RPS Integration Cost Study is to develop and define the procedures needed for routine calculation of the indirect integration costs for eligible renewable generators. This report documents findings of the RPS Integration Cost Study and the methodologies for evaluating the integration costs of renewable generators. The recommended calculation procedures are suitable for routine application on a continuing basis as part of the resource procurement process. Other indirect costs not addressed include investments in new transmission capacity and cost associated with remarketing electricity already purchased in long term supply contracts.

Publication Number 500-04-054. July 2004. [http:// www.energy.ca.gov/reports/500-04-054.PDF].

Accelerated Renewable Energy Development.

This draft staff white paper addresses specific policies related to accelerated renewable energy development in both central-station and distributed generation applications. Following the recommendations of the 2003 *Integrated Energy Policy Report (Energy Report)*, this white paper discusses the following key policy issues:

Post-2010 renewable energy goals
Differential utility targets
Possible use of unbundled renewable energy certificates in future years of the RPS and
Key issues for renewable distributed generation, primarily distributed photovoltaic (PV) generation.

As part of the discussion of central-station renewables, this draft staff white paper highlights some of the key transmission-related challenges for renewable energy. Some concentrated areas of renewable energy potential are located far from existing transmission lines or would connect to transmission lines that are already fully utilized. The availability of transmission for these renewables is a barrier to renewable development in the state.

This white paper was prepared to support the *2004 Energy Report Update* proceeding. This paper provides background information regarding the estimated energy and incentive levels available from key renewable energy programs in California, including RPS programs, and distributed PV generation commercialization programs.

Draft Staff White Paper. Publication Number 100-04-003D. July 2004. [http://www.energy.ca.gov/2004_policy _update/documents/2004-08-23_workshop/2004-07-30_100-04-003D.PDF].

Upgrading California's Electric Transmission System: Issues and Actions for 2004 and Beyond.

This paper discusses several key issues and the next steps necessary to continue implementing a fully collaborative state transmission planning process: capturing the strategic benefits, planning for corridors, and adequately assessing the alternatives to a transmission project. In addition, this paper summarizes the status of high-priority transmission projects currently under review. For this white paper, the Energy Commission staff brought together stakeholders to further the collaborative planning process initiated in 2003.

Draft Staff White Paper. Publication Number 100-04-004D. July 2004. [http://www.energy.ca.gov/ 2004_policy_update/documents/2004-08-23_workshop/2004-07-30_100-04-004D.PDF].

Renewables Portfolio Standard: Decision on Phase 2 Implementation Issues.

This report represents the Renewables Committee's proposed recommendations to the Energy Commission on Phase 2 issues in the RPS proceeding. This report is divided into two sections. The introductory section summarizes the report scope and development process, as well as discusses the legislative requirements of SB 1078 and SB 1038 for each of the following Phase 2 issue areas:
Distributing supplemental energy payments (SEPs),
Certifying renewable electricity generation facilities, and
Developing the accounting system for the RPS.

The report then presents the Renewables Committee's proposed decisions, as well as the rationale for those decisions, for each issue area.

This report also addresses the relationship between the Renewable Energy Program (REP) established by Senate Bill 90 and the RPS as it relates to new renewable facilities.

Final Committee Draft. Publication Number 500-03-049FD. [http://www.energy.ca.gov/ portfolio/ documents/2003-09-29_hearing/2003-09-29_FINAL_REP_PHS_II.P].

California's Electricity Generation and Transmission Interconnection Needs Under Alternative Scenarios.

This report is designed to help policymakers focus on the long-term and take steps now to plan for a robust and secure electricity infrastructure. Ultimately, a balanced and diversified resource strategy would utilize conservation, load management, renewables, distributed generation, and new interconnections and power plants. California also needs to plan for its future electricity needs by addressing other issues, e.g., fuel mix, energy efficiency, siting, transmission, and gas transportation. This report does not advocate any particular fuel source. It attempts to paint the situation in 2030 and concludes that new interconnections to resource-rich regions and new market hubs will be a part of California's future, and therefore California needs to take steps now to meet its future electricity needs.

Consultant Report. Publication Number 700-04-003. March 2004. [http://www.energy.ca. gov/reports/2004-03-24_700-04-003.PDF].

Wind Target Solicitation Workshop Presentation.

Presentation covering various topics and agenda items, including a detailed overview of the Energy Commission PIER wind program. Slides included description of program and strategy, R&D goals and objectives, summary of research efforts, and identification of key transmission and integration issues that need to be addressed.

Energy Commission. Public Interest Energy Research (PIER). Wind Target Solicitation Workshop. 2004. Prepared by Dora Yen-Nakajuji, Michael Kane.

***California RPS Integration Cost Analysis – Phase I: One Year Analysis of Existing Resources*.**

This report presents the results of Phase I of the California RPS Renewable Generation Integration Costs Study. The goal of the study is to develop a methodology for determining the integration costs of California RPS eligible renewable generation projects. The study was motivated by the RPS's "least-cost, best-fit" bid selection criterion which requires that indirect costs be considered in addition to the energy bid price when selecting eligible renewable projects. The methodology will produce cost adders which can be added to a project's bid price during the bid selection process. Integration costs are a subset of indirect costs and are defined as the costs and values of integrating an electrical resource such as a generation project into a system-wide electrical supply. Three primary categories of integration costs have been identified: capacity credit, regulation cost, and load following cost.

Work concentrated on evaluating renewable generator attributes (new technology, location of resource, etc) that can potentially improve and/or change initial Phase I results. The focus was on wind & geothermal resources since these resources are anticipated to achieve the greatest market penetration in the near-term.

Consultant Report. Publication Number 500-03-108C. December 2003.
[http://www.energy.ca.gov/ reports/2004-02-05_500-03-108C.PDF].

***Renewable Resources Development Report*.**

A comprehensive Energy Commission report focusing on key topics, such as the benefits of renewable development, policies driving renewable development, a situation analysis of renewables in California, a technology assessment for each of the renewable resources that can satisfy the RPS requirement, the renewable resource technical potential within California, and an assessment of the amount of renewable electricity required to meet the statewide RPS by 2017, as well as the accelerated RPS by 2010.

This report is follow-on to the Energy Commission's report Preliminary Renewable Resource Assessment (PRRA) delivered to the CPUC on July 1, 2003. The PRRA covered requirements for renewable resources for the investor-owned utilities (IOUs) and Electric Service Providers/Community Choice Aggregators. This report not only covers those entities, but also covers requirements for the entire state. This report includes updated information on proposed wind development in Riverside County, as well as additional wind potential in Kern County. As concluded in the PRRA and also illustrated in this report, California and the remaining states in the Western Electricity Coordinating Council (WECC) have considerable renewable resources, well in excess of the existing RPS requirements for all WECC states.

The Energy Commission staff estimates that the additional procurement of renewable energy needed to achieve the statewide RPS goals is 4,230 GWh/year in 2005, 13,120 GWh/year for 2008, and 30,610 GWh/year in 2017. This report concludes that there are enough proposed renewable energy projects and undeveloped technical potential for renewable energy resources in California to meet the statewide RPS requirements. Out-of-state renewable energy resources are also eligible to participate in RPS bid solicitations, provided that certain criteria are met.

Energy Commission staff estimates that the additional procurement of renewable energy needed statewide to achieve the accelerated RPS goal as confirmed in the Energy Action Plan is 6,120 GWh/year by 2005, 17,850 GWh/year by 2008, 24,800 GWh/year by 2010, and 30,610 GWh/year by 2017. The mix of renewable resources and locations used to meet the RPS will be determined by the bids received in response to renewable energy solicitations. The staff has developed scenarios for how the RPS and an accelerated RPS could possibly be met. The scenarios are primarily based on renewable energy projects that have already been proposed in the state.

Publication Number 500-03-080F. November 2003.
[http://www.energy.ca.gov/reports/2003-11-24_500-03-080F.PDF].

Aging Natural Gas Power Plants in California.

Staff paper provides a summary of capacity, usage, and emission characteristics of older natural gas power plants in California, as of July 2003. Key information presented is on the 25 largest natural gas fired facilities. Unit age distribution and forced outage parameters are addressed. Paper summarizes that reserve forecasts appropriately incorporate the reliability of the generation facilities in the state.

Staff Paper. Publication Number 700-03-006. July 2003. [http://www.energy.ca.gov/reports/2003-07-17_700-03-006.PDF].

***California's 2003 Electricity Supply and Demand Balance And Five-Year Outlook*.**

State wide peak supply and demand balance is presented for the period 2003 to 2008, including projected operating reserve for the five year outlook. Monthly information is presented for 2003. Methodology used for calculating the reserve margin takes into account the probability of both weather driven demand (both 1-in-2 and 1-10 year) and dry hydro conditions (1-in-5 year) on the supply side.

Figure 5: 2003-2008 Statewide Supply/Demand Balance. [http://www.energy.ca.gov/electricity/2003_SUPPLY_ DEMAND_PEAK.PDF].

***Intermittent Wind Generation: Summary Report of Impacts on Grid System Operations*.**

Report provides an assessment of wind energy production in leading wind regions around the globe including German, Spain, Denmark, Japan, and other nations. This report addresses certain questions such as: what are the issues associated with large-scale wind integration and what empirical data do we have from Europe, Japan and the US, how do system characteristics in Europe differ from the WECC and the CA ISO systems?, How will wind generation affect the physical operations of the grid? This report also contains a reference list of other studies, reports, and documents related to global renewable generation.

Consultant Report prepared by KEMA – XENERGY. Publication Number 500-04-091. June 2004. [http://www.energy.ca.gov/reports/CEC-500-2004-091.PDF].

California Public Utilities Commission

Report to the Legislature. SB 1038/Public Utilities Code Section 383.6: Electric Transmission Plan for Renewable Resources in California. Commission Report.

The Plan has two sections: a policy text that describes key issues emerging from the development of the Plan, and a Transmission Plan detailing the lines, facilities and costs by California county group under the two scenarios of renewable generation identified by the Energy Commission in its Renewable Resources Development Report in pursuant Code Section 383.5.

Key policy issues raised by this study include coordinating transmission development across Investor-owned Utility (IOU) service territories to maximize the return on ratepayer investments and avoid unnecessary duplication of facilities; coordinating with the ISO to enable a state total-resource perspective and to better understand the impact of intermittent resources on the grid; grouping, where possible, on a transmission facility renewable resources having complementary time profiles of production in order to maximize transmission capacity utilization; utilizing transmission capacity made available when non-renewable resources are displaced by RPS generation; and developing a new method of transmission financing that allows small renewable generators to participate in the RPS.

The detailed Transmission Plan describes transmission line and substation additions and modifications necessary to attain the legislative target of 20 percent RPS in 2017, as well as in 2010, as envisioned under the joint-agency Energy Action Plan.

This Plan is not intended to directly integrate with the related renewables procurement process of Code Section 399.15. Instead the transmission requirements for the renewable resources procured under the “least cost, best fit” criterion of Code Section 399.15 will be assessed separately for each generation project bid.

The Plan also describes the CPUC’s proposed reforms to California’s system of transmission needs assessment, which will develop a collaborative process with the CA ISO to eliminate duplicative effort, while keeping this process coupled to the CPUC’s ongoing resource planning and procurement efforts.

December 2003. [http://www.cpuc.ca.gov/ PUBLISHED/REPORT/32197.htm].

California Independent System Operator

Quantifying The Impact Of Wind Energy On Power System Operating Reserves.

The paper describes a new method for evaluating the impact of wind and other intermittent generation resources on the regulation and load following reserve requirements. The method is based on a realistic model mimicking the hour-ahead scheduling process, real-time dispatch, and automatic generation control performed by a Control Area Operator. The method allows quantifying the additional amount of regulation and supplemental energy (expressed in megawatts and dollars) that is needed each hour to accommodate intermittent resources into the grid. The proposed method evaluates the impacts of any improvement introduced in forecasting and scheduling of intermittent resources. It is flexible enough to accommodate specific practices of different Control Areas. Example results for the year 2002 of total California wind generation impacts are provided and discussed.

Prepared by Yuri Makarov and David Hawkins of the CA ISO. Presented at the Global Wind Power Conference and Exhibition. Chicago. March 28-31, 2004. [http://www.awea. org/global04.html].

California ISO Wind Generation Forecasting Service Design and Experience.

This article outlines a major CA ISO-led project that aims incorporating wind power generation into the California Energy Market and providing state-of-the-art forecasting services for participating wind power producers. This paper focuses on the CA ISO experience gained with wind generation forecasting requirements and methods. A sufficiently accurate hour-ahead forecasting is important to make wind power producers competitive as energy market bidders. It was found that, for the newly designed market principles, the monthly forecast error bias is even more important than the error itself.

The article discusses the CA ISO experience with its persistence forecasting models and newly developed bias self-compensation scheme. The hands-on experience with the CA ISO algorithm also helped to work out the hardware and informational structures implementing the Project. They are also discussed in the paper.

Prepared by Yuri Makarov and David Hawkins of the CA ISO. [http://www.ee. usyd.edu.au/~yuri/Windpower %202002 %20 Presentation-ver2.ppt].

Short-Term Regional Wind Forecasting Project Presentation**.**

Overview presentation by CA ISO staff on renewable generation in the United States, main wind generation regions within California, comments on issues and actions, and an illustrative structure of short-term regional forecaster.

Prepared by Yuri Makarov and David Hawkins of the CA ISO for the EPRI Power Delivery & Markets Meeting, NY, NY. March 2003. [http://www.ee.usyd.edu.au/~yuri/Yuri%20Makarov% 20Presentations.htm].

Transmission System Operators – International

2004 Wind Report; Wind Year 2003 – An Overview.

An overview report of wind statistics for the E.ON Netz control area for the year 2003. At the end of 2003, Germany total installed capacity of wind power plants was around 14,350 Megawatts (MW). Of this, the greatest proportion at around 6,250 MW was connected in the E.ON Netz control area. This report summarized wind operating data that illustrated some significant operational challenges of wind integration. Some of these operational challenges included:

Only limited wind power is available. In order to cover electricity demands, traditional power station capacities must be maintained as so-called “shadow power stations” at a total level of more than 80 percent of the installed wind energy capacity, so that the electricity consumption is also covered during economically difficult periods.

Only limited forecasting is possible for wind power in feed. If the wind power forecast differs from the actual in feed, the transmission system operator must cover the difference by utilizing reserve capacity. This requires reserve capacities amounting to 50 – 60 percent of the installed wind power capacity.

Wind power requires a corresponding grid infrastructure. For example, the windy coastal regions of Schleswig-Holstein and Lower Saxony are precisely the places where the grids have now reached their capacity limits through wind power. At present, just under 300 km of new high-voltage and extra-high voltage lines are being planned there in order to create the transmission capacities required for transporting the wind power.

E.ON Netz. Dr. Hanns Bouillon, Peter Fösel, Dr. Jügen Neubarth, Dr. Wilhelm Winter, editors. [http://www. nowhinashwindfarm.co.uk/EON_ Netz_Windreport_e_eng.pdf].

European Aspects of Wind Energy Integration into Liberalised Markets.

Presentation provides an overview of wind energy development in Germany by transmission provider. Issues covered include: interconnection transit capacity requirements for offshore development, system load versus wind production time line illustrating wind production variance, technical limits of wind power generation including thermal overload, voltage stability, and frequency stability. Identifies need for infrastructure including reactive power compensation, and balancing and reserve power for stable operation.

Euro E.ON Netz. -Case Workshop, Düsseldorf, Germany. Presentation by Matthias Luther. November 2003. [http://www.eurocase.orgActivities/wind_energy/Luther.pdf].

Eltra System Report 2004.

This report presentsthe mapping of plans for increases and decreases in production capacity in Western Denmark including electricity consumption forecast for the period 2004 to 2013. Recorded wind penetration is 19 percent. Report chapters address: (1) Security of Supply in the Eltra Area, (2) Procurement of Regulating Power and Ancillary Services, (3) Wind Power Requirements of the Grid, (4) Compliance with environmental Targets, and (5) Transmission Capacity.

Summary and Conclusion key issues include: (1) Wind power determines need for regulation power, (2) Access to ancillary services, (3) Expansion of the 400 kV grid, (5) Connections to neighboring areas, (6) Security of operations in the area, (7) Emergency management in the electricity supply, and (8) New production technologies.

Eltra. Denmark. http://www.eltra.dk/media(15998,1033) /Systemplan_2004-GB.pdf and *Eltra System Report 2003.* Denmark. http://www.eltra.dk/media 15114,1033)/ Systemplan_2003.pdf.

Eltra Annual Report 2003.

2003 annual report of Eltra, the transmission system operator in western Denmark.

Eltra. Denmark. [http://www.eltra.dk/media(15796,1033)/ Annual_Report_ 2003.pdf].

Eltra's Purchases of Ancillary Services and Regulating Reserves.

Addresses Eltra's purchases of ancillary services and regulating reserves during the autumn of 2003. Discussion of the regulating power market, regulating reserves, ancillary services, and market for regulating reserves and ancillary services is provided. A description of products is provided including primary reserves, regulating reserves – automatic, and regulating reserves manual.

Eltra. Denmark. [http://www.eltra.dk/media(15104,1033)/Eltra%27s_Purchases.pdf].

Guideline for Eltra's Market Report.

The market report guideline presents a description and definition of market parameters reported on including consumption, generation, imports, exports, etc.

Eltra. Denmark. [http://www.eltra.dk/media (15269,1033)/Vejledning_
til_markedsrapporten_til_GB.pdf].

***Market Report – January 2004*. Denmark.**

Sample market report provides a time line of tie line capacity and physical flows between Norway, Sweden, and Germany. A graphic also illustrate the degree to which Western Denmark depends on the Nordic Pool and Germany to balance its load and resource generation by means of importing and exporting.

Eltra. [http://www.eltra.dk/media (15445,1033)/01_-_January_-_GB.pdf].

Other References

Measuring Generator Performance in Providing Regulation and Load-Following Ancillary Service.

Supply side analysis performed focusing on regulation and load-following services. Load-following differs from regulation in three important aspects (1) it occurs over longer time intervals than does regulation—10 min or more rather than minute to minute, (2) load-following patterns of individual customers are highly correlated with each other, whereas the regulation patterns are largely uncorrelated, and (3) load-following changes are often predictable and have similar day-to-day patterns. An additional metric was added to load-following: interchange schedules.

Report Number ORNL/TM-2000/383. Prepared by Eric Hirst and Brendan Kirby for the Oak Ridge National Laboratory. December 2001. [http://www.ornl.gov/~webworks/cppr/y2001/rpt/109482.pdf].

Customer-Specific Metrics for the Regulation and Load-Following Ancillary Service.

Report discusses customer-specific costs associated with regulation and load following. Two load-following metrics were examined (1) load-following magnitude measured as the difference between the maximum and minimum values of 30-minute rolling-average load during each hour and (2) load-following rate measured as the ratio of the first metric divided by the number of minutes between the highest and lowest load values. Costs are assigned based on hourly metrics and quantifies load-following ramp rate as a function of load values.

Report Number ORNL/CON-474. Prepared by Brendan Kirby and Eric Hirst for the Oak Ridge National Laboratory. January 2000. [www.ornl.gov/~webworks/cpr/rpt/105927.pdf].

The Integration of Renewable Energy Sources into Electric Power Transmission Systems.

Assessments of the need for additional transmission capacity to develop renewable energy resources were requested by the Conference Report, H.R. 102-177, for the Energy and Water Development Appropriations Bill, 1992, Public Law 102-104. This report documents assessments of the capability of existing transmission systems to support the integration of wind and solar plants in specific renewable resource areas. The assessments evaluate existing transmission capacity and identify the need for new or upgraded transmission lines.

Prepared for the Oak Ridge National Laboratory by Martin Marietta Energy Systems, Inc. Report Number ORNL-6827. 1995
[http://www.ornl.gov/~webworks/cpr/v823/rpt/81522.pdf].

The Effects of Integrating Wind power on Transmission System Planning, Reliability, and Operations. Report on Phase 1: Preliminary Overall Reliability Assessment.

This Report is an assessment of the impact of large-scale wind generation on the reliability of the NY State Bulk Power System (NYSBPS). Assessment includes:
Review of world experience with wind generation
Fatal flaw power flow analysis
Reliability analysis
Review of current planning and operating practices

This report recommends NY State require all new wind farms to have best practices on interconnection requirements including the following proven technology:

Voltage regulation at the Point-of-Interconnection, with a guaranteed power factor range.
Low voltage ride-through
A specified level of monitoring, metering, and event recording
Power curtailment capability

The following features are emerging in response to system needs:
Ability to set power ramp rates
Electrical governor functions
Reserve functions
Zero-power voltage regulation

The largest impact of wind generation on NY State system operations is expected to be on load following reserves and unit commitment. Phase II report, due the end of the year, will make this System Performance Evaluation. Impact on regulation is not expected to be substantial.

Fatal Flaw Powerflow Analysis allows the NY State system to reach a 10 percent level of penetration without restriction.

Reliability analysis addresses the Loss of Load Expectation (LOLE) of 0.1day/year.

Report recommends NY State planning and operating practices be modified to account for the presence of significant wind generation in the state. Procedures which may need to be modified include:
Calculation of operating reserves, regulation and load following requirements in the presence of wind generation
Calculation of unforced capacity value of wind generation
Consideration of wind generation in transmission planning
Test requirements for the Dependable Maximum Net Capacity (DMNC) measurement of wind generation
Operating procedures for operation with impending severe weather conditions

Assessment results indicate that the NY State should be able to integrate wind generation to a level of at least 10 percent of the system peak load (a total of about 3300 MW of wind generation) without significant adverse impacts on planning, operations, and reliability of the bulk power system, provided that appropriate wind farm requirements and operations practices are adopted when needed.

GE Power Systems Energy Consulting. Prepared for the New York State Energy Research and Development Authority. February 2004. [http://www.uwig.org/phase%20_1_feb_02_04.pdf].

Wind Power Impacts on Electric Power Systems Operating Costs: Summary and Perspective on Work to Date.

This paper was presented at an American Wind Energy Association Global Wind Power Conference and presented a summary of various case studies examining the variability of wind-plant output and the cost impact on ancillary services. Three key conclusions of this paper were: First, the incremental cost of ancillary services attributable to wind power is low at low wind penetration levels; as the wind penetration level increases, so does the cost of ancillary services; Second, the cost of ancillary services is driven by the uncertainty and variability in the wind plant output, with the greatest uncertainty in the unit-commitment time frame, or day-ahead market. Improving the accuracy of the wind forecast will result in lower cost of ancillary services; and Third, at high penetration levels the cost of required reserves is significantly less when the combined variations in load and wind plant output are considered, as opposed to considering the variations in wind plant output alone.

The study results also concluded that even at moderate wind penetrations, the need for additional generation to compensate for wind variations is substantially less than one-for one and is generally small relative to the size of the wind plant.

Presented at the AWEA Global Wind power conference. Prepared by J. Charles Smith (Utility Wind Interest Group), Edgar A. DeMeo (Renewable Energy Consulting Services Inc.), Brian Parsons (National Renewable Energy Laboratory), Michael Milligan (National Renewable Energy Laboratory) March 2004. [http://www.uwig.org/windpower2004.pdf].

***Wind Integration Study – Final Report*.**

This study is a comprehensive, quantitative assessment of integration costs and reliability impacts for 1500 MW of planned wind generation in the Xcel Energy control area in the year 2010 with a projected peak load of 10,000 MW. Study focus was on issues, and functions related to short-term planning, scheduling of generation resources, and operation of the control area in real-time, including addressing the contribution of wind generation loss of load probability (LOLP) to power system reliability. Transmission issues are not addressed.

Reliability implications focused on the effective load carrying capability (ELCC) of the proposed wind generation. The ELCC capability was quantified using the General Electric (GE) MARS (Multi-Area Reliability Simulation) program.

Power system operation impacts identified include regulation, load following, scheduling, and unit commitment. Wind integration costs are addressed for these operational impacts. Analysis results for integrating the 1500 MW of wind generation into the Xcel control area in 2010 are no higher than $4.60/MW of wind generation, and are dominated by costs incurred by Xcel to accommodate the significant variability of wind generation and the wind generation forecast errors for the day-ahead market. This total cost includes ~ $0.23/MWh for regulation and load following.

A nominal increase in ramping capability was identified.

EnerNex Corporation. Prepared for the Minnesota Department of Commerce. September 2004. [http://www.uwig.org/ XcelMNDOCStudy Report.pdf].

Characterizing the Impacts of Significant Wind Generation Facilities on Bulk Power System Operations Planning. Xcel Energy – North Case Study.

This report investigates the impacts of large wind generation resources on power system operations and scheduling functions. Emphasis is on quantifying the costs associated with these impacts as utilities evaluate all-source energy purchase alternatives. Study utilizes Xcel Energy actual utility data with the objective of:

- Conducting a quantitative investigation of large wind plant operating impacts on utility operation planning;
- Identifying operating cost impacts (for host utility system);
- Evaluating the value of reduced wind forecast uncertainty;
- The operational impact of wind generation integration is a simulation-based approach designed to determine the ancillary service cost incurred by Northern States Power (Xcel Energy) to accommodate their existing 280 MW windplant. Three time scales are investigated including 3-day ahead for performing hourly unit commitment, 1-hour ahead with 5-minute resolution for performing intra-hour load following, and 1-hour ahead with 4-second resolution for performing load frequency control.

Cost impacts were assessed using the developed simulation models and these included:
Cost of wind generation forecast inaccuracy for day-ahead scheduling
Cost of additional load following reserves
Cost on intra-hour load following "energy component"
Cost of additional regulation reserves

Electrotek Concepts, Inc. Final Report. Prepared for The Utility Wind Interest Group. May 2003. [http://www.uwig.org/UWIGOpImpactsFinal7-15-03.pdf].

System Operations Impacts of Wind Generation Integration Study.

Electrotek Concepts, Inc. conducted an impact study for integrating wind generation into the power grid for year 2012. Four wind sites in Wisconsin were addressed with total wind capacities of: 250, 500, 1000, and 2000 MW. The study objective was to calculate the ancillary services cost impact of this wind generation into We Energies' system.

Four types of cost impacts were identified and evaluated including:
Inter-hour variability
Regulation
Intra-hour load following
Hour-ahead forecast uncertainty

A ProSym^{TM} simulation based model was used to calculate the cost impacts of wind integration. Total incremental ancillary service cost for wind integration including regulation, intra-hour load following, and hour-ahead forecast uncertainty ranged from \$1.90 to \$2.92/MWh. Total wind production capacities ranged from 250 to 2000 MW on the projected 7000 MW system in 2012.

Some discussion of ancillary service requirements is included.

Electrotek Concepts, Inc. Prepared for We Energies Energy System Operations. July 2003. [http://www.uwig.org/WeEnergiesWindImpacts_FinalReport.pdf].

Grid Impacts of Wind Power: A Summary of Recent Studies in the United States.

This conference paper provides technical investigations of grid ancillary service impacts of wind power plants in the U.S. including the Xcel Energy, PacifiCorp, and BPA systems. Paper describes the cost estimates of wind integration for the three utility time frames at issue including regulation, load following, and unit commitment. Study findings indicate that large-scale wind generation will have an impact on power system operation and costs.

Paper discusses the emerging methods for analyzing the grid impact of wind. A general background on control area operational parameters is provided. Two analytical studies addressing Lake Benton II/PJM and Iowa and three utility cases including UWIG study of Xcel Energy, PacifiCorp IRP, and Hirst BPA study are presented. These studies provide an early indication of ancillary service costs imposed by wind and all of them found that wind integration impacts and cost are non-zero and become more significant at higher wind penetrations.

Parsons, Brian and Milligan, Michael, et al. Draft presentation at the European Wind Energy Conference, June, 2003. Madrid, Spain. [www.nrel.gov/wind/pdfs/grid_integration_studies_draft.pdf].

Assessing the Impact of Wind Generation on System Operations at Xcel Energy – North and Bonneville Power Administration.

The paper presents the Utility Wind Interest Group research projects to quantify the cost impacts of integrating wind plants on the Xcel Energy – North (Xcel) and BPA systems. The general analysis approach was to use the tools utilized by the respective utilities to simulate the respective operational procedures to determine the cost impacts of integrating their respective wind plants. The operational and scheduling systems requirement to integrate the variability of wind generation is examined for various control time frames.

Xcel Energy – North Case Study is the groundwork for the final report presented in reference 25. Preliminary findings address the: 1) Cost of Wind Generation Forecast Inaccuracy, 2) Load Following Cost of Wind Generation, and 3) variance in Control Performance for Regulation.

BPA's objective was to determine the impact of wind integration (1,200 MW) on BPA's hydro operations and on the ability to export energy out of the BPA region. Preliminary study results were not complete at publication time. A preliminary analysis framework is presented. The hourly operations impact study addresses three scheduling time frames: monthly, pre-schedule, and real-time (next hour). The aggregate cost impact of wind on the hydro and transmission systems was to be compared with the no wind scenarios to estimate cost impacts.

Electrotek, Inc. Presented at the Wind Power 2002 Conference. [http://www.uwig.org/opimpactspaper.pdf].

***Draft Final, Wind Generation Technical Characteristics for the NYSERDA Wind Impacts Study*.**

Report examines present day wind turbine and wind plant technologies that will be added to the NY State Bulk Power System (NYSBPS). Wind plant design, configuration, and performance characterization for power system studies is covered including:
Steady-State
Dynamic Response
Transient
Short Circuit Contributions

Turbine and wind plant parameters are quantified for power system studies in two time frames, baseline (CY2006) and CY2013.

EnerNex Corporation. Prepared by R.M. Zavadil. November 2003. [http://www.uwig.org/wind_turbine_tech_charac_draft_final.pdf].

***Overview of Wind Energy Generation Forecasting*.**

State-of-the-art forecasting techniques exhibit considerable capability in the next hour and day-ahead forecasting time frames. Very short-term (0-6 hrs) hourly forecasts typically outperform a persistence forecast by 10 percent to 30 percent. Short-term (1-2 days) hourly forecasts usually outperform persistence and climatology forecasts by 30 percent to 50 percent. At the present, medium range (3-10 days) forecasts of the hourly wind energy production typically do not outperform climatology forecasts and hence have limited usefulness.

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Report on current wind power generation in Germany (14,500 MW EOP 2003) and the operational and cost implications for TSO's compensating for the fluctuating wind power production. The methodology for quantifying operational reserves is discussed. The conclusion is drawn that to ensure sustainable development of wind power generation new mechanisms are needed to assure cost responsibilities are allocated to those who are responsible for them: the producers of wind power.

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